

REMARKS

By the present Amendment, claims 1-14 are cancelled and claims 15-35 are added. This leaves claims 15-35 pending in the application, with claims 15 and 25 being independent.

Substitute Specification

The specification is revised to eliminate grammatical and idiomatic errors in the originally presented specification. The number and nature of the changes made in the specification would render it difficult to consider the case and to arrange the papers for printing or copying. Thus, the substitute specification will facilitate processing of the application. The substitute specification includes no "new matter". Pursuant to M.P.E.P. § 608.01(q), voluntarily filed, substitute specifications under these circumstances should normally be accepted. A marked-up copy of the original specification is appended hereto.

Rejections Under 35 U.S.C. § 103

Claim 15 covers a process for ignition of combustion of fuel in a combustion space 5 of an engine 2. The process comprises conveying fuel into the combustion space, producing microwave energy in a microwave source 7 located outside the combustion space, injecting the microwave radiation into and uniformly throughout the combustion space with fuel therein in at least one microwave pulse of short duration and of high energy, absorbing the microwave pulse by the fuel distributed into the combustion space, igniting the fuel uniformly over a large space in the combustion space by energy delivered into the fuel due to absorption of the microwave pulse essentially at the same time, and preventing formation of plasma by selection of a time interval for injecting of the microwave energy, of power of the microwave radiation, of pulse duration and of pulse spacing.

Claim 25 covers a device for igniting combustion of fuel in a combustion space 5 of an engine 2. The device comprises a microwave source 7 located outside of the combustion space and producing spaced microwave pulses. A microwave window 13 is connected to the microwave source through which the microwave pulses are injected in and uniformly throughout the combustion space of the engine to be absorbed by the fuel uniformly in all of the combustion space with the fuel being ignited uniformly by the microwave pulses when absorbed by the fuel due to the energy delivery at the same time, without forming plasma by selection of a time interval for injecting the microwave pulses, of power of the microwave pulses, of pulse duration and of pulse spacing.

The process and device, as claimed, relates to igniting fuel in the combustion space of an engine by the injection of microwave radiation. The microwave radiation essentially ignites at the same time the fuel over a large volume in the combustion space. The microwave radiation is in the form of one or more pulses of short duration and high energy. The formation of a plasma is prevented in the combustion space by the choice of the time interval of injection of microwave energy, its power, its pulse duration and its pulse space.

None of the cited patents discloses or renders obvious this process or device.

Claims 1-10 stand rejected under 35 U.S.C. §103 as being unpatentable over U.S. Patent No. 4,138,980 to Ward. The Ward patent is cited for use of microwave radiation produced by microwave source 10 outside a combustion space such that the microwave radiation is absorbed by the fuel distributed into the combustion space of chamber 22. Col. 3, lines 37-35 of the Ward patent are relied upon regarding optimizing the coupling of the microwave energy for radiating the energy out to the flame. In support of the rejection, it is alleged that it would be obvious to

modify the Ward engine such that the microwaves are uniformly distributed in the entire combustion space to maintain equilibrium.

Relative to claim 2, the Ward patent allegedly discloses the microwave radiation being injected in pulses. Relative to claim 3, the Ward patent allegedly discloses the number power and duration of microwave pulses depending on engine operation. Relative to claim 4, the microwave characteristics are either disclosed or considered obvious to optimize. Relative to claim 5, the Ward patent is alleged to disclose microwave pulses of different power and duration, and modifying the Ward engine to guarantee leveling of the temperature increase to the ignition temperature is alleged to be obvious optimization in view of the Ward disclosure at column 5, lines 40-57. Relative to claim 6, modifying the Ward engine, such that the plasma formation is dependent on pulse spacing, is alleged to an obvious optimization. Relative to claim 7, the Ward patent is cited as describing a device having a microwave source outside a combustion space provided by chamber 22 for injecting microwave energy into the combustion space through the fuel distributed in the combustion space. In support of the rejection, it is considered obvious to optimize the combustion space and microwave energy.

Relative to claim 8, the Ward patent is cited as supplying electrical pulses converted into microwave pulses. Relative to claim 9, the Ward patent is cited as disclosing a couple means 24 between a microwave source 10 and a microwave window provided by a spark plug 20, without transmitting microwaves reflected by the combustion space back into the microwave source. Relative to claim 10, the coupling means 24a is alleged to have a triple port with a circulator provided by distributor 12, with a microwave source 10 connected to the first port 24a and a

microwave window provided by spark plug 20 connected at 18a to a second port, and a passive microwave consumer 16, 24a-28a connected to its third port.

Claim 11 stands rejected under 35 U.S.C. §103 as being unpatentable over the Ward '980 patent in view of U.S. Patent No. 4,297,983 to Ward. The Ward '983 patent is cited for a microwave window (opening in coupler 50) made of ceramic material. In support of the rejection, it is alleged that it would be obvious to make the Ward '980 window of ceramic material.

Claims 12-13 stand rejected under 35 U.S.C. §103 as being unpatentable over the Ward '980 patent and the Ward '983 patent, in view of U.S. Patent No. 2,563,952 to Nichol. The Nichol patent is cited for a flexible microwave line 19, which allegedly would be obvious to use in the Ward '980 system.

The Ward patent, cited and applied against the claims of this application, involves a technique for increasing the efficiency of an internal combustion engine by exciting a resonant mode of the engine's combustion chamber. The exciting of the resonant mode in the Ward patent produces standing waves within the combustion chamber (col. 3, line 42; col. 4, line 8). This resonant mode is continuously excited (col. 2, lines 34-36) and uses a continuous wave magnetron (col. 4, lines 51-52). The power level of the radio frequency energy is on the order of 100 watts, i.e., between 10 watts and 1,000 watts (col. 5, line 34-35), particularly 600 watts (col. 7, line 59). In the Ward system, the radio frequency energy is coupled to a combustion plasma air-fuel mixture, preferable at a plasma frequency (col. 2, lines 32-34).

Contrary to the system disclosed in that Ward patent, the present invention involves a process and device in which microwave energy is injected in the form of one or more pulses of

short duration and time, and is not injected to continuously as in the Ward patent. In this manner, the claimed process and device are patentably distinguishable over the Ward patent by the microwave pulse or pulses. Relative to microwave pulses, col. 3, lines 37-45, the Ward patent is particularly cited. Although this portion of the Ward patent discloses varying frequencies with corresponding wavelengths, such are done to produce standing waves or cavity modes to maintain continuous high electric fields. Such disclosure does not constitute a microwave pulse or spaced microwave pulses of short time duration and high energy, as alleged. Cycles of the microwave radiation do not constitute pulses that have a definitive beginning and end, and a spacing, in contrast to the Ward patent continuous supply of radiation to providing standing waves.

Additionally, the Ward system involves the formation of a plasma. In contrast, the present claimed invention prevents formation of the plasma. The Ward patent control of frequency/oscillation does not correspond to the control of pulse duration and spacing, as recited in the claims. The Ward plasma formation further patentably distinguishes the claimed process and device over the Ward patent.

Further, the present claimed invention uses the microwave energy in the form of microwave pulses to ignite the fuel. In contrast, the Ward patent only uses radio frequency energy to enhance precombustion conditioning, with the ignition being initiated by spark plugs 20. Thus, the claims are further patentably distinguishable over the Ward patent by the ignition by microwave pulses.

Accordingly, claims 15 and 25 are patentable distinguishable over the Ward patent. None of the other cited patents cure these deficiencies in the cited and applied Ward patent.

Claims 16-23 and claims 26-34, being dependent upon claims 15 and 25, respectively, are also allowable for the above reasons. Moreover, these dependent claims recite additional features further distinguishing them over the cited patents.

Claim 16 is further distinguished by the by the controlling of the number, power, duration and timing of the microwave pulses depending on the operating state and power demand of the engine. Since the Ward patent does not disclose microwave pulses, it cannot disclose controlling pulses, as claimed. The control of electromagnetic wave frequencies does not produce or control microwave pulses. None of the other cited patents discloses such control.

Claim 17 is further distinguished by the microwave radiation being injected in 1 to 10 spaced microwave pulses. No such number of pulses are disclosed in the cited patents, particularly since the Ward patent merely discloses a continuous application to produce standing waves.

Claims 18 is further distinguished by the 1 to 5 spaced microwave pulses. As noted above, such microwave pulses are not disclosed in the Ward patent.

Relative to claims 17 and 18, Ward patent col. 5, line 42 is cited. However, such citation refers to the creation of standing waves by the maintenance of continuous high electric fields, and not of 1 to 10 or 5 spaced microwave pulses, as claimed.

Claim 19 is further distinguished by the power of the microwave pulses being between 1 kW and 70 kW. No such power levels are disclosed or rendered obvious by the Ward patent. Relative to claim 19, the Ward patent, col. 5, line 35 is cited. However, this line only refers to a range of 10 watts to 1000 watts, and not of 1 kW to 70 kW, as claimed.

Claim 20 is further distinguished by the pulse duration being between 1 ns and 2 ms. No such duration is disclosed or rendered obvious by the Ward patent. Relative to the pulse of claim 20, a frequency cycle apparently is relied upon as alleged to produce a cycle of 3.3 ns. However, a cycle is not a pulse, and thus, does not satisfy the claim limitation.

Claim 21 is further distinguished by the microwave pulses being spaced by between 100 ns and 2 ms. No such spacing is disclosed or rendered obvious by the Ward patent. Relative to claim 21, it is alleged to be obvious to provide pulse spacing. However, such spacing would be directly contrary to the Ward disclosure of producing continuous radiation in order to produce standing waves. Thus, one of ordinary skill in the art would not find it obvious to modify the Ward device to provide such spacing in order to produce pulses, as claimed.

Claim 22 is further distinguished for the reasons advanced above relative to claim 17, 19 and 20.

Claim 23 is further distinguished for the reasons advanced above relative to claim 18.

Claim 24 is further distinguished by the recitation of several microwave pulses of different power or duration for leveling temperature increases of the fuel in the combustion space up to an ignition temperature by gradual delivery of energy. No such pulses are disclosed or rendered obvious by the Ward patent. Relative to claim 24, the Ward patent, col. 5, lines 40-57, is cited. Although this portion of the Ward patent speaks of producing a particular temperature, it does not speak of injecting radiation pulses of different power and pulse duration to produce the ignition temperature in the combustion space.

Claim 26 is further distinguished by the microwave window being mounted on the engine at its combustion chamber. No such microwave window is disclosed or rendered obvious by the Ward patent.

Claim 27 is further distinguished by the claimed electric power supply source delivering electrical signals to the microwave source converted to spaced microwave pulses by the microwave source. No such structure for generating spaced microwave pulses is disclosed or rendered obvious by the Ward patent.

Claim 28 is further distinguished by the coupling allowing microwave transmission into the chamber but avoiding transmission of microwaves reflected from the combustion space back into the microwave source within the overall claimed combination.

Claim 29 is further distinguished by the coupler being connected to the microwave source and the microwave window, within the overall claimed combination.

Claim 30 is further distinguished by the three ports being connected to the microwave source, microwave window and passive microwave consumer, respectively. No such connection is disclosed or rendered obvious by the Ward patent.

Claims 31 and 32 are further distinguish by the microwave window being ceramic material (claim 31) or formed completely of ceramic material (claim 32) within the overall claimed combination.

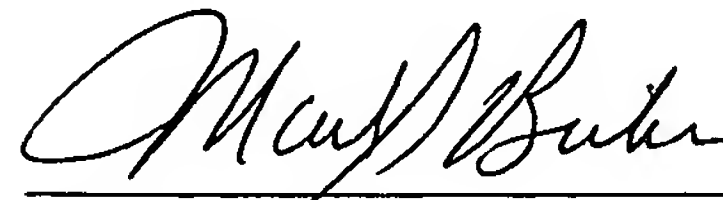
Claim 33 is further distinguished by the flexible line, within the overall claimed combination.

Claim 34 is further distinguished by the particular engines recited therein, within the overall claimed combination.

Claim 35 is further distinguished by the use of spaced microwave pulses.

In view of the foregoing, claims 15-35 are allowable. Prompt and favorable action is solicited.

Respectfully submitted,



Mark S. Bicks
Reg. No. 28,770

Roylance, Abrams, Berdo & Goodman, LLP
1300 19th Street, NW, Suite 600
Washington, DC 20036
(202) 659-9076

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